Habituation of anxiety and cortical hypervigilance during image-based exposure

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MPsych (Clin)

A report submitted in partial requirement for the degree of Master of Psychology (Clinical) at the University of Tasmania

Statement

I declare that this research report is my own work and that, to the best of my knowledge and belief, it does not contain material from published sources without proper acknowledgement, nor does it contain material which has been accepted for the award of any other higher degree or graduate diploma in any university.

Monique Williams _____ Date: _____

Acknowledgements

First and foremost, I would like to extend my upmost gratitude to my supervisor Dr Allison Matthews. Thank you for your endless guidance and support, optimism and creativity. Your expertise and mentorship has been invaluable to learn from. A special thanks the 2018 cognitive neuroscience lab crew. Sarah, Caleb, Jake, and Callula, it has been a pleasure working alongside you and having your support along the way. Thank you for your assistance with recruitment. A special mention to Tess Nikitenko who kindly gave time to pilot the task. To the 2017-18 masters cohort, thank you for your support throughout this project and a special thanks to those of you who helped with recruitment. Finally, a big thank you to the participants who took part in this investigation – your time, effort and interest in this project has made it all possible.

Abstract

Habituation (decreased response to stimuli with repeated exposure) of attentional hypervigilance (preferential allocation of attention to feared stimuli) was investigated in specific fear. Participants with high (n=13) or low (n=13) spider fear passively viewed bird (neutral) images and progressively 'scarier' spider (fear-relevant) and snake (negative) images, in separate six-stage hierarchies. Stage six contained the image from Stage one repeated. Electrophysiological (EEG) activity was recorded throughout and the P1 event-related potential (ERP) was taken as a cortical measure of attentional hypervigilance. Participants rated their subjective anxiety (Subjective Units of Distress Scale; SUDS) at four timepoints for each stage (0, 30, 60, 90 seconds). Both groups showed reductions in P1 amplitude at Stage 3 compared to Stage 1 in the spider image hierarchy, and compared to Stages 1 and 2 in the snake image hierarchy. Both groups also demonstrated re-emergence of P1 amplitude at Stage 6 compared to Stage 3 of the spider and snake hierarchies. High but not low spider fear participants showed habituation of subjective anxiety within later spider image stages (4-6), but there was little evidence of habituation between stages. Together, findings do not provide evidence for a fear-specific neural mechanism during image-based exposure. Findings may otherwise reflect covert avoidance of, or dishabituation of visual attention towards, evolutionary threat images. It difficult to determine if participants attended to images given the use of a passive viewing paradigm and the graded task may have confounded arousal with habituation. Future research may employ eye-tracking technology and non-graded stimuli.

In vivo exposure therapy is the gold standard treatment for specific phobia, involving graded progression through increasingly feared exposure stages (Choy, Fyer, & Lipsitz, 2007). Despite evidence of robust treatment gains, barriers to utilisation of face-to-face exposure therapy include low acceptance of treatment, high rates of drop-out (Choy et al., 2007), as well as costs and restrictions in access (Andersson & Titov, 2014). Online image-based exposure has the potential to overcome these barriers, with evidence of effectiveness in specific phobia (e.g., Matthews, Naran, & Kirkby, 2015). Furthermore, image-based exposure offers a way to investigate mechanisms involved in exposure treatment.

In exposure treatment, one index of therapeutic change is *habituation*. This refers to a gradual reduction in anxiety in response to the feared stimuli with repeated exposure (Foa, Huppert, & Cahill, 2006). Habituation of self-reported and physiological measures of anxiety has been observed in high spider fear participants during image-based exposure of spiders (e.g., Matthews, Naran, & Kirkby, 2015). According to Emotional Processing Theory, initial activation of fear followed by habituation between and within sessions leads to integration of new information in stimulus-response associations that are discordant with the previous fear response (Foa et al., 2006). This is argued to allow corrective learning to take place (Foa et al., 2006). In contrast, inhibitory learning perspectives focus on extinction learning or a decreased learned response to a conditioned stimulus (Craske, 2015). Original fear associations between the unconditioned stimulus and conditioned stimulus are not erased but inhibited by new associations that represent safety (Craske, 2015). Thus, retention of part of the original association can lead to *reinstatement* or the resurfacing of a fear response after

multiple presentations of the aversive stimulus following extinction (Craske, 2015). Despite differences, these theories both emphasise the role of attentional processing of feared stimuli as a pre-requisite for successful exposure (Podina, Koster, Philippot, Dethier, & David, 2013).

Specific attentional hypervigilance refers to rapid and preferential attentional processing of fear-relevant compared to neutral stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). This has been observed in individuals with a specific phobia and is thought to play a maintaining role in anxiety disorders (Bar-Haim et al., 2007; Kolassa, Musial, Mohr, Trippe, & Miltner, 2005). According to Attentional Control Theory, anxiety promotes bottom-up processing and facilitates attention to threat (Eysenck, Derakshan, Santos, & Calvo, 2007). This may be underpinned by amygdala hyperactivity (Bishop, 2007), as this structure is implicated in automatic processing of fear (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003) and sends neural projections directly to the visual cortex (Jacobs, Renken, Aleman, & Cornelissen, 2012). Amplitude of the P1 event-related potential (ERP) component can serve as a cortical measure of attentional hypervigilance as it indexes early visual processing (peaks approximately 100ms post-stimulus) and is modulated by selective attention (Mangun, 1995). This has been demonstrated in high relative to low spider fear participants through increased P1 amplitude in response to spider compared to neutral images (Venettacci, Johnstone, Kirkby, & Matthews, 2017).

It is of interest to investigate whether a cortical measure of attentional hypervigilance habituates in a similar way to anxiety with repeated exposure to feared stimuli. Reductions in P1 amplitude over repeated unpleasant images has been found in

females without a specified anxiety disorder (Olofsson & Polich, 2007). However, increases in P1 amplitude over repeated neutral stimuli was found, suggesting differential effects of image valence on early attentional processes. Furthermore, O'Toole and Dennis (2012) found training attention away from threatening images reduced P1 amplitude in response to both threatening and non-threatening images in non-anxious participants with an initial bias towards threat. This suggests modification of attentional hypervigilance may lead to generalised reductions in P1 amplitude. To date, one study has investigated habituation of P1 amplitude during graded image-based exposure in specific fear (Matthews, Mackintosh, Williams, Williams, & Kirkby, 2017). In this study, high compared to low fear participants showed greater P1 amplitude overall across six stages in a hierarchy of progressively "scarier" spider images. However, both groups demonstrated similar habituation of P1 amplitude across stages 3, 4, and 5. This was despite habituation of self-reported anxiety via Subjective Units of Distress Scale (SUDS) ratings across stages 1-6 in high fears, but not low fears, who showed low SUDS ratings throughout. Furthermore, when the stage 1 image was repeated at stage 6, both groups showed increased P1 amplitude to a level consistent with that shown at stage 1, albeit amplitude being lower overall for low fears. This may suggest specific attentional hypervigilance followed by generalised rather than fear-specific habituation and reinstatement.

As Matthews et al. (2017) exclusively used fear-relevant stimuli, it is difficult to determine whether their findings reflect a fear-specific process involving habituation and reinstatement of attentional hypervigilance. Inclusion of neutral and negative, non-fear relevant images would enable evaluation of whether this process is observable

irrespective of the emotional valence of stimuli. Additionally, is it possible that participants covertly avoided “scarier” images at the later stages of the hierarchy (3, 4 and 5), leading to the observed reductions in P1 amplitude. While this seems unlikely to have also occurred in low fear participants, inclusion of neutral and negative images is needed to further assess this.

The aim of the current study was to further investigate habituation of attentional hypervigilance and its relevance to habituation of anxiety among high and low spider fear participants during a similar graded exposure paradigm to that used by Matthews et al. (2017). In addition to a fear-relevant (spider) image hierarchy, negative (snake) and neutral (bird) image hierarchies were used for comparison. P1 amplitude was examined as a cortical measure of attentional hypervigilance. It was hypothesised that high relative to low fear participants would show greater self-reported anxiety ratings (SUDS) and P1 amplitude for spider images overall compared to snake and bird images, reflecting heightened anxiety and attentional hypervigilance in response to feared stimuli. High relative to low fear participants were expected to show between-stage habituation of initial fear activation (as measured by SUDS) for spider relative to snake and bird image hierarchies. If exposure results in habituation of attentional hypervigilance to feared stimuli, similar reductions in P1 amplitude were expected in high relative to low fear participants. If reinstatement of attentional hypervigilance to feared stimuli occurs, high relative to low fear participants were predicted to show an increase in P1 amplitude in response to the repeated image at Stage 6 for the spider relative to snake and bird image hierarchies.

Method

Research Participants

The sample comprised 26 females (13 high fear) aged 18-38 years old (*M*=24.3, *SD*=6.4). Only females were recruited to control for possible sex differences in cognitive or emotional processing (Lusk, Carr, Ranson, Bryant, & Felmingham, 2015). Additionally, greater rates of phobia and fear has been reported in females compared to males (Oosterink, de Jongh, & Hoogstraten, 2009). G*Power 3.1.9.2 estimates indicated sample sizes of 15 per group were sufficient to detect moderate sized effects (*f*=0.25) (alpha=.05, power=.9).

A total of 194 females completed the screening questionnaire. It was aimed to recruit those with scores in the upper (19 or above) and lower (6 or below) quartile on the Spider Phobia Questionnaire (SPQ; Watts & Sharrock, 1984). In the final sample, high and low fear participants' scores fell in the 54th (14 or above) and 29th (6 or below) percentile, respectively. Participants also had a low fear of snakes (<8 Snake Phobia Questionnaire; Klorman, Weerts, Hastings, Melamed, & Lang, 1974) and birds ($\leq$3 bird fear rating from 0-8). Participants were either recruited through advertisement at the University of Tasmania (UTAS) or on social media, or were undergraduates at UTAS who were reimbursed with participation course credit.

The exclusion criteria included a history of neurological or psychiatric disorder (other than anxiety or depression), seizure, serious physical condition, head injury, loss of consciousness (>five minutes), pregnancy, previous treatment for spider phobia, current use of psychoactive medication (other than Selective Serotonin Reuptake Inhibitor/SSRI antidepressants), illicit drug use within the last month or more than 50

lifetime occasions, or potential alcohol dependence (≥16 on Alcohol Use Disorders Identification Test; Babor, Higgens-Biddle, Saunders, & Monteiro, 2001). Participants were also asked to abstain from caffeine (2 hours), tobacco (2 hours), alcohol (24 hours) and illicit drugs prior to the experimental session. All participants reported being right handed, except one participant who did not report handedness.

Instruments and Materials

Questionnaire measures. The Spider Phobia Questionnaire (SPQ; Watts & Sharrock, 1984) includes 33 yes/no questions to assess preoccupation, vigilance, and coping/avoidance in response to spiders (e.g., "*would you get help if you came across a spider?*"). Five items are reverse scored and higher overall scores indicate greater fear. Ten filler items assessing knowledge about spiders were deemed irrelevant for the current study and were removed. The SPQ has been shown to have convergent validity with other measures of anxiety and excellent test-retest reliability (r =.94) (Muris & Merckelbach, 1996). Excellent internal consistency was shown in the present sample (Cronbach's α=0.94).

The Fear of Spiders Questionnaire (FSQ; Szymanski & O'Donohue, 1995) was used as a secondary measure of spider fear. This includes 18 items rated on a 7-point Likert scale (1=definitely not, 7=absolutely). Higher scores indicate greater fear. The FSQ has been shown to have convergent validity with other measures of anxiety and excellent test-retest reliability (r=.91) (Muris & Merckelbach, 1996). Excellent internal consistency was shown in the present sample (Cronbach's α=0.99).

The Snake Phobia Questionnaire (SNAQ; Klorman, Weerts, Hastings, Melamed, & Lang, 1974) was used as a measure of snake fear. This includes 30 'yes'\'no' items

(e.g., "*I am terrified by the thought of touching a harmless snake*"). Seven reversal items are included and higher scores indicate greater fear. The SNAQ has been shown to have good discriminant validity and internal consistency (Klorman et al., 1974). Poor internal consistency was shown in the present sample (Cronbach's α=0.27). However, it is noted that a number of items showed low variability in participant responses, consistent with a homogenous (low snake fear) sample.

The State-Trait Anxiety Inventory Form Y-2 (STAI; Spielberger, 1983) was used to measure trait anxiety. The trait anxiety sub-scale comprises 20 items on a 4-point Likert scale (1=almost never, 4=almost always), where higher scores indicate greater trait anxiety. This sub-scale has been shown to have good convergent validity with other measures of anxiety (e.g., Antony, Bieling, Cox, Enns, & Swinson, 1998).

The Subjective Units of Distress Scale (SUDS; Wolpe, 1969) was used to measure subjective state anxiety. Respondents were required to rate their current level of anxiety on a single scale (10=no anxiety, 100=extreme anxiety).

The Kessler Psychological Distress scale (K10; Kessler et al., 2002) measures psychological distress over the last four weeks. Ten items are rated on a 5-point Likert scale (1=all of the time, 5=none of the time). Higher scores indicate greater distress. Excellent internal consistency was shown in the present sample (Cronbach's α=0.92).

The Alcohol Use Disorders Identification Test (AUDIT; Babor, Higgins-Biddle, Saunders, & Monteiro, 2001) measures alcohol consumption levels and symptoms of dependence. A score of 16 or above indicates potentially harmful use. The AUDIT has been shown to have good convergent and discriminative validity (Bohn, Babor, & Kranzler, 1995).

The Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) provides a measure of verbal intellectual functioning. Fifty irregularly spelled words are pronounced and one point is scored for each correct response. The test is discontinued if 12 incorrect responses are given consecutively. The WTAR has shown convergent validity with other measures of intellectual functioning and good test-retest reliability (*r*=.90-.94) (Wechsler, 2001).

The Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990) measures subjective sleepiness on a single 9-point scale (1=very alert, 9=very sleepy, great effort to stay awake, fighting).

A Video Gaming Experience Questionnaire (VGEQ) was used to measure frequency of video game play. This comprised a single question rated on a 5-point scale (1=never play video games, 5=often play video games, more than 5 hours a week) (see Appendix A). The VGEQ was developed for the current study to control for a potential confound given evidence that regular video gamers show some enhanced skills in visual attention (Dye, Green, & Bavelier, 2009). Psychometric properties of the VGEQ have not yet been assessed.

Image-based exposure task. A pilot study was conducted to select images for the image-based exposure task. A total of 53 participants completed a survey where they were asked to provide their level of spider, snake, and bird fear each via a single question (rated from 0 to 10). The survey also included the SPQ, FSQ and SNAQ (see Appendix B). Participants were then asked to rate 15 coloured images each of huntsman spiders, snakes and sparrow birds (obtained from online databases with a Creative Commons license) on a scale of 0 to 10 in terms of valance (0=highly pleasant,

10=highly unpleasant), arousal (0=low arousing, 10=highly arousing) and scariness (0=not scary at all, 10=highly scary) (see Appendix B). A median split was conducted for spider and snake fear. No significant interactions between group and image were found for spider or snake images. Thus, the whole sample's ratings were used to rank these images. Five of each snake and spider images with mean 'scariness' ratings progressing from 'low' to 'high', and five bird images with low mean 'scariness' ratings were selected for the paradigm. Ratings for selected images also showed a pattern of progressive arousal and negative valence ratings for spider and snake images and stable arousal and valance ratings for bird images (although skewed slightly on the positive end for both arousal and valence) (see Appendix C).

For each 6-Stage image hierarchy, Stage 6 comprised the repeated Stage 1 image. Each image was 126mm length x 82mm height presented for 1s on a black screen with the inter-stimulus-interval varied randomly across three stimulus onset asynchronies: 400ms, 500ms, 600ms. There were 90 trials per stage for each hierarchy, totaling 1.5 minutes of exposure per stage, and a total completion time of 13.5 minutes for each hierarchy. Total task length was 40.5 minutes. The order of image hierarchy presentation (spider, snake, bird) was counterbalanced across three orders according to a Latin square design.

Electrophysiological (EEG) recording. A NeuroSCAN system (Scan 4.5 software) was used with a 32-channel Quik-Cap with Ag/AgCl sintered electrodes. EEG data was recorded from 32 sites, using the international 10-20 system of electrode placement. Electrode impedance was kept below 10kΩ. Data was sampled continuously at a rate of 1000Hz and averaged offline for a 1000ms epoch commencing 100ms prior

to stimulus presentation. Electrodes were placed on the outer canthi of both eyes and the upper and lower left eye to measure horizontal and vertical electro-oculographic (EOG) activity. All electrodes were referenced to linked mastoids. EEG data was filtered with a Zero-phase-shift FIR low pass filter (30Hz, 24 dB/Oct). Ocular artefact rejection was used to reduce the impact of eye blinks on other electrode channels. Epochs were extracted from the data from 100ms before stimulus onset to 900ms post stimulus. Baseline correction and artefact rejection was applied to trials containing artefacts above 70 μV and below -70 μV. The occipital P1 component was defined as the maximum amplitude between 70-120ms post stimulus onset and was derived from grand averaged waveforms for each condition. Peaks outside this timeframe were manually marked during peak detection.

Procedure

The current study was approved by the University of Tasmania Human Research Ethics Committee. Participants attended an experimental session of approximately two and a half hours. Participants were first given an information sheet, provided informed consent, and then were asked about their caffeine, nicotine, alcohol, drug and prescription medication use to ensure that they were still eligible. They then completed questionnaires for information regarding their current sleepiness (KSS), anxiety (STAI), video gaming (VGEQ), and verbal intellectual ability (WTAR). Following EEG set-up, participants completed the three image-based exposure tasks, sitting approximately 50cm away from a computer screen. Prior to viewing the first image of each stage, participants provided their baseline SUDS rating, then subsequent ratings after each 30 seconds of exposure (i.e., four time points for each image: 0, 30, 60, 90 seconds). To

minimise potential fatigue, breaks were given between image hierarchies. Participants then provided valence (1=highly unpleasant to 9=highly pleasant) and arousal (1=low arousing/not at all exciting to 9=highly arousing/very exciting) ratings for the 15 task images, presented in randomised order. Debriefing was provided at the end of sessions.

Design and Data Analysis

Peak P1 amplitude was analysed with a 2 (Fear group: high fear, low fear) x 3 (Animal: Spider, Snake, Bird) x 6 (Stage: 1, 2, 3, 4, 5, 6) mixed ANOVA. The same analysis was used for mean SUDS ratings, with the variable Timepoint (0s, 30s, 60s, 90s) added. Post-task valence and arousal ratings were analysed with a 2 (Fear group: high fear, low fear) x 3 (Animal: Spider, Snake, Bird) x 5 (Image: 1, 2, 3, 4, 5) mixed ANOVA.

P1 amplitude at electrode site Oz was selected as a central measure of occipital activity. ANOVA was chosen for the current study, as this is consistent with the conventional and parsimonious approach in ERP literature (Luck, 2014). Only significant ($p < .05$) effects and interactions of theoretical relevance were further analysed with tests of simple effects. Bonferroni corrections were applied to keep the familywise error rate at .05 for initial effect break-downs. To counter likely violations of sphericity, Greenhouse-Geisser corrections were applied to effects with more than two levels. Cohen's *d* was used as an effect size measure for pairwise comparisons and was interpreted in line with Cohen's (1992) guidelines (0.2=small, 0.5=medium, 0.8=large). For omnibus ANOVAs, partial eta square was provided as an estimate of the proportion of variance in a dependent variable accounted for by the independent

variables (Cohen, 1988). These effect sizes were interpreted as 0.01=small, 0.06=medium, 0.14=large (Cohen, 1988).

Results

Demographics

Table 1 shows that there were no statistically significant differences between groups on age, intellectual functioning (WTAR), sleepiness on the day of testing (KSS), video gaming experience (VGEQ), alcohol usage (AUDIT), trait anxiety (STAI), psychological distress (K10), or snake fear (SNAQ). Higher bird fear among high relative to low fear participants trended towards statistical significance, but average scores were both less than 2 out of 8, reflective of low bird fear. As expected, high fear participants had greater scores on measures of spider fear (SPQ, FSQ).

Image Ratings

Valence ratings. There were significant main effects of Animal, $F(2,46)=46.0$, $p<.001$, $\eta_p^2=.657$, and Image, $F(3,74)=9.6$, $p<.001$, $\eta_p^2=.286$. However, these effects were modified by the statistically significant Animal x Image interaction (see Table 2), $F(4,96)=3.5$, $p=.010$, $\eta_p^2=.129$. The effect of Image was statistically significant for Spider, $F(2,46)=13.5$, $p<.001$, $\eta_p^2=.361$, Snake, $F(3,76)=4.7$, $p=.004$, $\eta_p^2=.164$, but not Bird images, $F(3,64)=0.5$, $p=.647$, $\eta_p^2=.021$ ($\alpha=.017$, Bonferroni corrected). Overall, participants rated Spider Image 1 as less negative than 4 ($p=.005$) and 5 ($p<.001$), with a trend for Spider Images 3 ($p=.024$). Image 2 was also rated as less negative than Image 5 ($p=.001$). When broken down, there were no statistically significant differences in valence ratings for images of Snakes or Birds.

Table 1

Mean Age and Raw Scores on Measures of Spider Fear, Snake Fear, Bird Fear, Sleepiness, Reading Ability, Video Game Usage, Alcohol Usage, Anxiety, and Psychological Distress for High and Low Spider Fear Groups

	Low fear	High fear			
Variable	*M* (*SD*)	*M* (*SD*)	*F*(1, 25)	*p*	Cohen's *d*
Age	23.9(6.0)	24.8(7.1)	0.1(1, 25)	.722	0.14
SPQ/33	2.9(1.7)	18.5(4.2)	150.6(1, 25)	<.001	4.81
FSQ/126	21.6(5.3)	95.7(17.2)	220.5(1, 25)	<.001	5.82
SNAQ/30	3.7(2.3)	5.0(1.9)	2.5(1, 25)	.124	0.63
Bird fear/8	0.4(0.7)	1.1(1.0)	4.2(1, 25)	.053	0.81
KSS/9	4.2(1.4)	3.3(0.9)	2.8(1, 25)	.105	0.66
WTAR/50	112.2(7.9)	107.5(11.2)	1.6(1, 25)	.222	0.49
VGEQ/5	0.5(0.9)	0.5(0.9)	0.1(1, 25)	.825	0.09
AUDIT/40	4.5(3.3)	4.5(3.5)	0.0(1, 25)	1.0	0.00
STAI/80	34.9(9.3)	39.6(12.2)	1.2(1, 25)	.280	0.43
K10/50	18.4(5.7)	19.1(7.8)	0.1(1, 25)	.798	0.10

Table 2

Descriptive Statistics for Valence Ratings for Spider, Snake and Bird Images across Stages

	Spider		Snake		Bird	
Image	*M*(*SD*)	95%CI	*M*(*SD*)	95%CI	*M*(*SD*)	95%CI
1	4.0(1.3)	[3.5, 4.5]	5.1(1.4)	[4.5, 5.6]	6.7(2.0)	[5.9, 7.5]
2	3.7(1.6)	[3.0, 4.3]	4.9(1.3)	[4.4, 5.4]	6.3(1.6)	[5.7, 7.0]
3	3.4(1.9)	[2.6, 4.1]	5.1(1.5)	[4.5, 5.7]	6.4(1.8)	[5.7, 7.2]
4	2.8(1.6)	[2.2, 3.5]	5.2(1.7)	[4.5, 5.9]	6.5(1.8)	[5.7, 7.2]
5	2.4(1.2)	[1.9, 2.9]	4.0(1.8)	[3.3, 4.8]	6.7(1.8)	[5.9, 7.4]

Note. Scores range from 1=highly unpleasant to 9=highly pleasant.

There was a statistically significant Animal x Group interaction (see Figure 1), $F(2,46)=7.7$, $p=.002$, $\eta_p^2=.242$. Overall, high fear participants rated Spider images as more negative compared to low fear participants, $F(1,24)=26.6$, $p<.001$, $\eta_p^2=.526$ ($\alpha=.017$, Bonferroni corrected). There were no statistically significant differences between high and low fear participants' ratings for Snake, $F(1,24)=0.3$, $p=.570$, $\eta_p^2=.014$, or Bird images, $F(1,24)=1.1$, $p=.305$, $\eta_p^2=.044$. The Animal x Image x Group interaction did not reach statistical significance, $F(4,96)=1.4$, $p=.226$, $\eta_p^2=.057$.

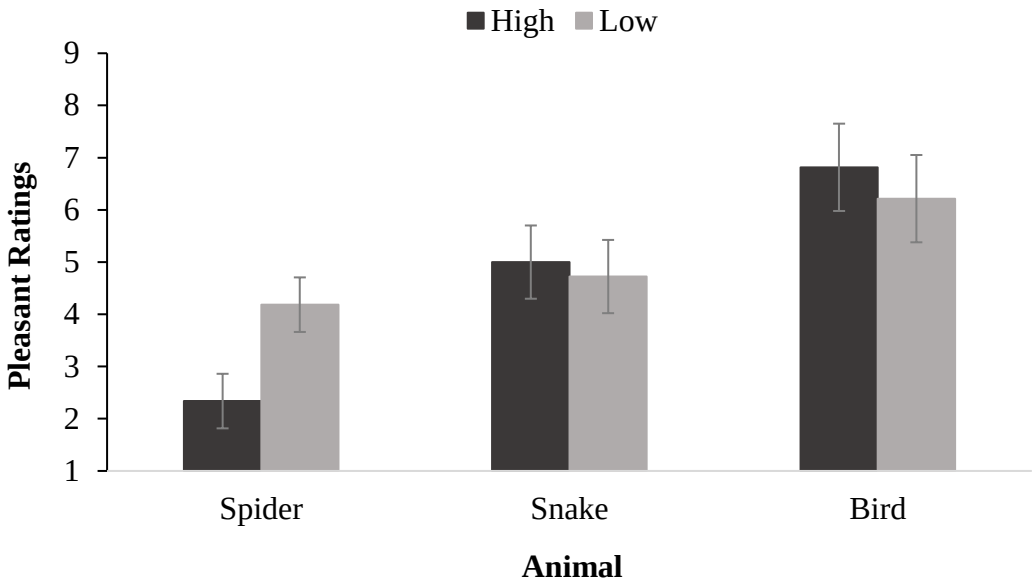

Figure 1. Mean valence ratings for spider, snake and bird images among high and low fear participants (error bars represent 95% CIs). Scores range from 1=highly unpleasant to 9=highly pleasant.

Arousal ratings. There were statistically significant main effects of Animal, $F(2,47)=18.7$, $p<.001$, $\eta_p^2=.438$, and Image, $F(3,76)=9.9$, $p<.001$, $\eta_p^2=.292$. However, these were qualified by the statistically significant Animal x Image interaction (see Table 3), $F(4,91)=4.2$, $p=.005$, $\eta_p^2=.148$. There was an effect of Image for Spiders, $F(2,56)=6.7$, $p=.002$, $\eta_p^2=.219$, Snakes, $F(2,55)=6.2$, $p=.002$, $\eta_p^2=.206$, with Birds trending towards statistical significance, $F(3,61)=2.8$, $p=.058$, $\eta_p^2=.104$ ($\alpha=.017$, Bonferroni corrected). For Spider images, Image 5 ($p=.004$) and 3 ($p=.001$) were both rated as more arousing than Image 1. For Snake images, Image 5 trended towards significance for higher arousal ratings compared to Image 1 ($p=.018$). There were no statistically significant differences in arousal ratings for Bird images.

Table 3

Descriptive Statistics for Arousal Ratings for Spider, Snake and Bird Images across Stages

	Spider		Snake		Bird	
Image	*M*(*SD*)	95%CI	*M*(*SD*)	95%CI	*M*(*SD*)	95%CI
1	3.2(2.1)	[2.3, 4.0]	2.4(1.6)	[1.7, 3.0]	2.3(2.0)	[1.5, 3.1]
2	3.5(2.5)	[2.5, 4.5]	2.2(1.8)	[1.5, 3.0]	1.7(1.2)	[1.2, 2.2]
3	4.3(2.4)	[3.3, 5.2]	2.8(2.1)	[2.0, 3.7]	1.7(1.5)	[1.1, 2.3]
4	4.0(2.2)	[3.1, 4.9]	2.7(2.0)	[1.9, 3.5]	1.9(1.6)	[1.2, 2.5]
5	4.5(2.2)	[3.6, 5.3]	3.4(2.0)	[2.6, 4.2]	1.8(1.9)	[1.1, 2.6]

Note. Scores range from 1=low arousing (not at all exciting) to 9=highly arousing (very exciting).

There was a statistically significant main effect of Group, $F(1,24)=8.7$, $p=.007$, $\eta_p^2=.267$. However, this was qualified by the statistically significant Animal x Group interaction (see Figure 2), $F(2,47)=81.6$, $p<.001$, $\eta_p^2=.326$. High fear participants rated Spider images as significantly more arousing than low fear participants, $F(1,24)=38.8$, $p<.001$, $\eta_p^2=.618$ ($\alpha=.017$, Bonferroni corrected). There were no statistically significant differences between groups in arousal ratings for Snake, $F(1,24)=0.3$, $p=.605$, $\eta_p^2=.011$, or Bird images, $F(1,24)=0.9$, $p=.354$, $\eta_p^2=.036$. The Animal x Image x Group interaction was not statistically significant, $F(4,91)=0.4$, $p=.782$, $\eta_p^2=.017$.

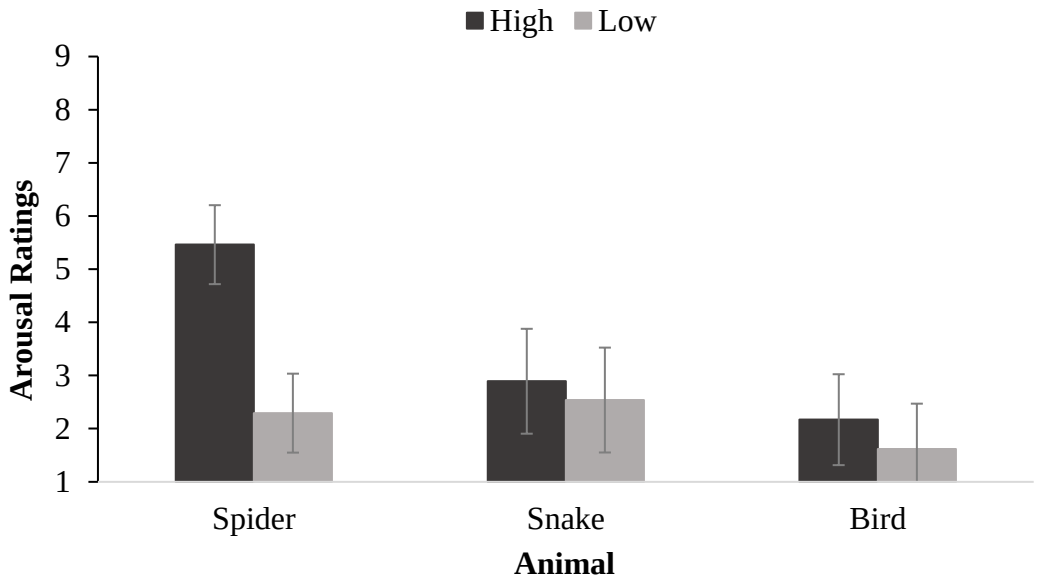

Figure 2. Mean arousal ratings for spider, snake and bird images among high and low fear participants (error bars represent 95% CIs). Scores range from 1=low arousing (not at all exciting) to 9=highly arousing (very exciting).

Peak P1 Amplitude

There was a statistically significant effect of Stage, $F(2,59)=3.6$, $p=.027$, $\eta_p^2=.129$. Overall, P1 amplitude was greater at Stage 1 ($M=9.5$, $SD=4.7$, 95% CI [7.6,11.4]) compared to Stages 3 ($M=8.2$, $SD=4.7$, 95% CI [6.3,10.1], $p=.003$) and 5 ($M=8.4$, $SD=5.1$, 95% CI [6.3,10.5], $p=.007$) ($\alpha=.008$, Bonferroni corrected). P1 amplitude trended towards being significantly greater for Stage 1 compared to Stage 4 (M=8.5, SD=5.4, 95% CI [6.3,10.7], p=.020). Compared to Stage 3, P1 amplitude was greater at Stages 2 ($M=9.1$, $SD=5.3$, 95% CI [7.0,11.2], $p=.002$) and 6 ($M=9.2$, $SD=4.5$, 95% CI [7.4,11.0], $p<.001$).

The Animal x Stage interaction was statistically significant (see Figure 3),

$F(5,123)=4.9$, $p<.001$, $\eta_p^2=.169$. The effect of Stage was statistically significant for Spider, $F(3,65)=7.3$, $p<.001$, $\eta_p^2=.233$, and Snake images, $F(3,82)=5.1$, $p=.002$, $\eta_p^2=.175$, but not for Bird images, $F(2,59)=0.8$, $p=.479$, $\eta_p^2=.032$ ($\alpha=.017$, Bonferroni corrected). For Spider images, P1 amplitude was significantly lower at Stage 3 compared to Stages 1 ($p=.001$, $d=0.58$) and 6 ($p=.004$, $d=0.52$), with moderate effect sizes. For Snake images, P1 amplitude was lower at Stage 3 compared to Stage 1 ($p=.006$, $d=0.48$), 2 ($p=.003$, $d=0.39$), with Stage 6 trending towards statistical significance ($p=.022$, $d=0.29$), with small effect sizes. For Bird images, there were no statistically significant differences in P1 amplitude between any of the stages. The hypothesised Animal x Stage x Group interaction was not statistically significant (see Figures 4, 5 and 6 for grand averaged waveforms), $F(5, 123)=0.8$, $p=.524$, $\eta_p^2=.034$, nor were any other effects including Group ($p>.05$).

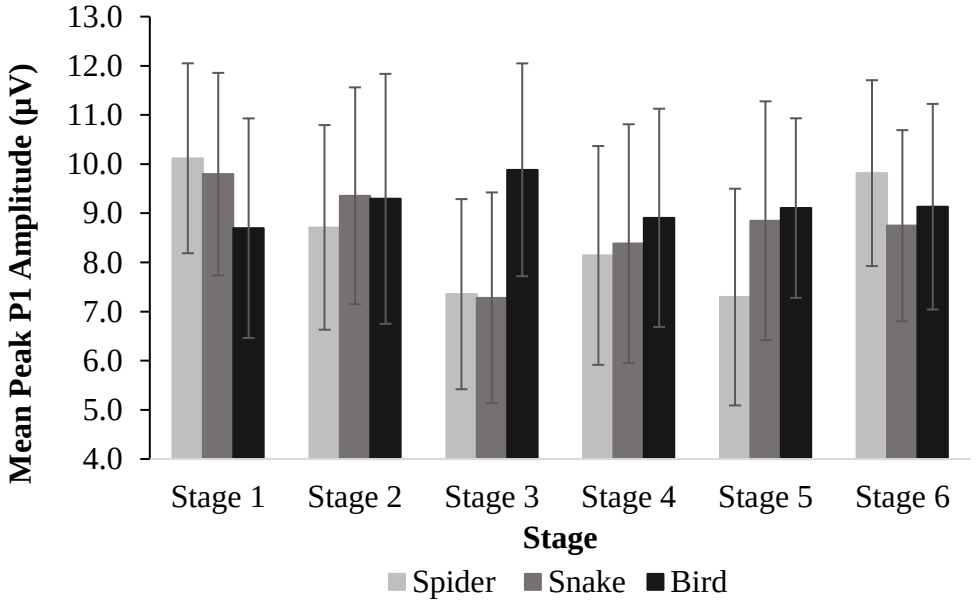

Figure 3. Mean P1 amplitude at the midline occipital electrode site (Oz) across stages for spider, snake and bird image hierarchies (error bars represent 95% CIs).

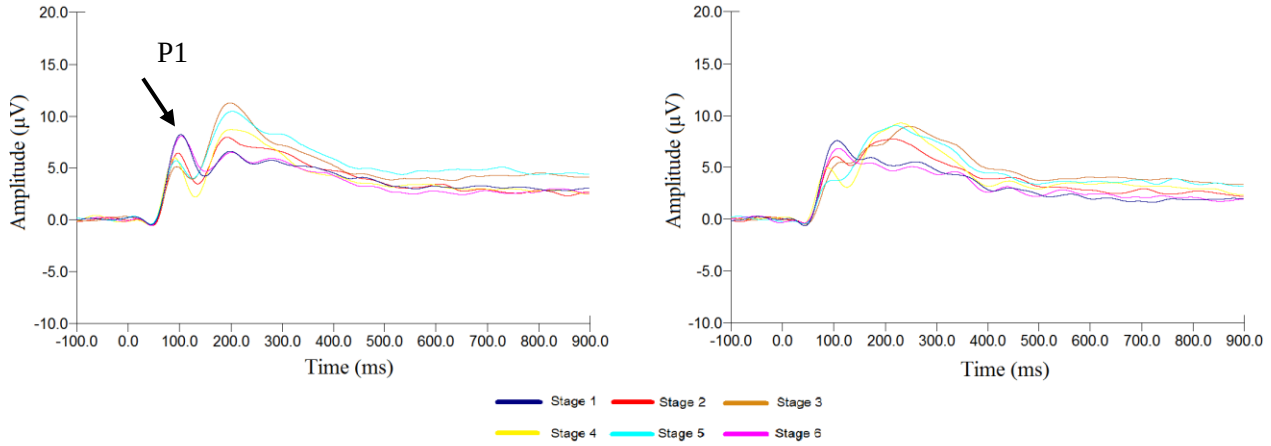

Figure 4. Grand averaged waveforms at the midline occipital electrode site (Oz) for high (left) and low (right) fear participants across stages for the spider image hierarchy.

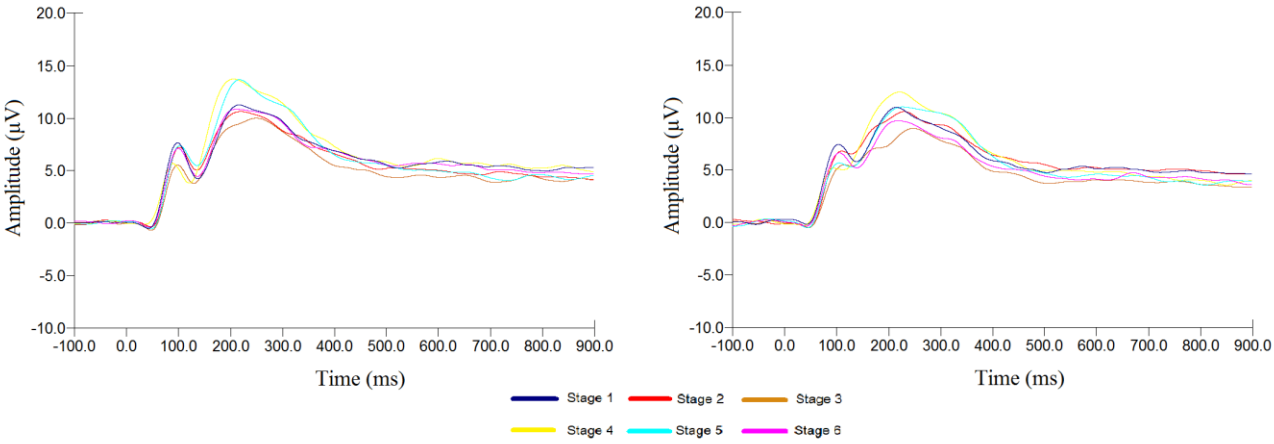

Figure 5. Grand averaged waveforms at the midline occipital electrode site (Oz) for high (left) and low (right) fear participants across stages for the snake image hierarchy.

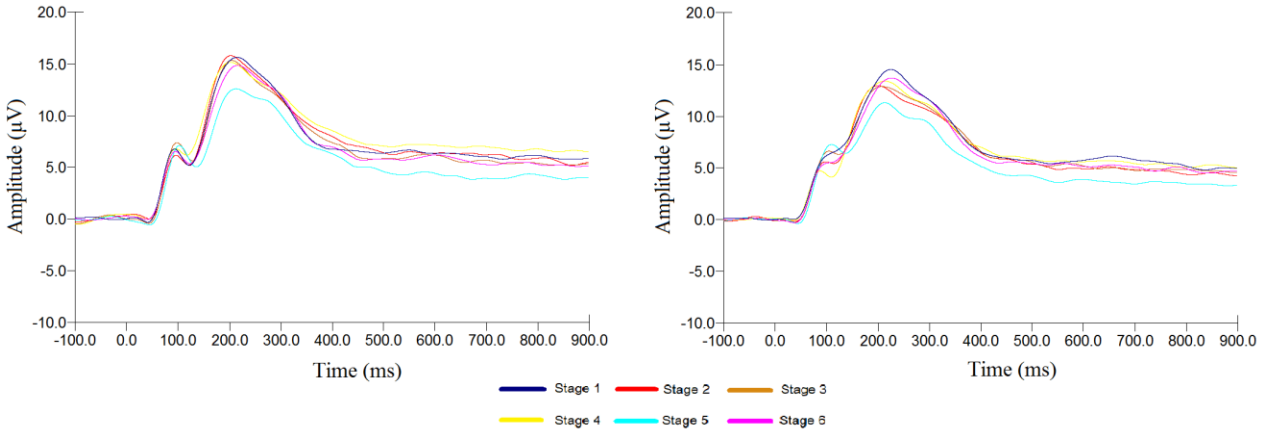

Figure 6. Grand averaged waveforms at the midline occipital electrode site (Oz) for high (left) and low (right) fear participants across stages for the bird image hierarchy.

SUDS

There were statistically significant main effects for Group, $F(1,24)=13.8$, $p=.001$, $\eta_p^2=.366$, and Animal, $F(1,30)=24.8$, $p<.001$, $\eta_p^2=.508$. However, these were qualified by the statistically significant hypothesised Animal x Group interaction, $F(1,30)=22.8$, $p<.001$, $\eta_p^2=.488$. Overall, high ($M=30.6$, $SD=14.4$, 95% CI [21.9,39.3]) compared to low fear participants ($M=11.8$, $SD=2.4$, 95% CI [10.3,13.2]) had higher SUDS ratings for Spider images, $F(1,24)=21.6$, $p<.001$, $\eta_p^2=.473$ ($\alpha=.017$, Bonferroni corrected). High ($M=12.2$, $SD=2.5$, 95% CI [10.7,13.7]) and low fear participants ($M=12.6$, $SD=4.7$, 95% CI [9.7,15.4]) did not significantly differ in their SUDS ratings for Snake images, $F(1,24)=0.1$, $p=.804$, $\eta_p^2=.003$. High ($M=11.2$, $SD=2.1$, 95% CI [9.9,12.5]) and low fear participants ($M=10.4$, $SD=1.2$, 95% CI [9.7,11.1]) also did not significantly differ in their SUDS ratings for Bird images, $F(1,24)=1.3$, $p=.268$,

η_p^2=.051.

The Animal x Stage x Group x Timepoint interaction reached statistical significance (see Figure 7), $F(6,144)=5.3$, $p<.001$, $\eta_p^2=.180$. The Animal x Stage x Timepoint interaction was significant for high, $F(5,57)=7.7$, $p<.001$, $\eta_p^2=.390$, but not low fear participants, $F(7,79)=1.6$, $p=.138$, $\eta_p^2=.121$ ($\alpha=.025$, Bonferroni corrected). For high fear participants, the Stage x Timepoint interaction was statistically significant for Spider images, $F(3,36)=9.2$, $p<.001$, $\eta_p^2=.434$, trended towards statistical significance for Snake images $F(3, 41)=3.1$, $p=.031$, $\eta_p^2=.206$, but not Bird images, $F(3,36)=1.9$, $p=.141$, $\eta_p^2=.140$. For Spider images at Stage 3, high fear participants' SUDS ratings increased from 0 to 30 seconds ($p=.009$, $d=1.07$), with a large effect size, $F(2,20)=10.9$, $p=.001$, $\eta_p^2=.475$. For Stage 4, SUDS were decreased at 90 seconds compared to 30 ($p=.004$, $d=0.53$) and 60 seconds ($p=.001$, $d=0.30$), with moderate and small effect sizes, respectively, $F(1,17)=5.7$, $p=.020$, $\eta_p^2=.322$. For Stage 5, SUDS were decreased at 60 ($p=.007$, $d=0.29$) and 90 seconds ($p=.002$, $d=0.57$) compared to at 30 seconds, with small and moderate effect sizes, respectively, $F(1,17)=5.6$, $p=.021$, $\eta_p^2=.319$. For Stage 6, SUDS were decreased at 90 seconds compared to 0 ($p=.017$, $d=0.85$) and 30 seconds ($p=.005$, $d=0.26$), with large and small effect sizes, respectively, $F(1,14)=9.5$, $p=.007$, $\eta_p^2=.442$. There were no statistically significant differences between Timepoints ($p>.025$) for Stages 1, $F(1,17)=2.8$, $p=.102$, $\eta_p^2=.189$, and 2, $F(1,18)=5.6$, $p=.020$, $\eta_p^2=.319$. All other main effects and interactions reached statistical significance ($p<.05$), except for the Timepoint x Group interaction, $F(1,33)=2.3$, $p=.131$, $\eta_p^2=.088$.

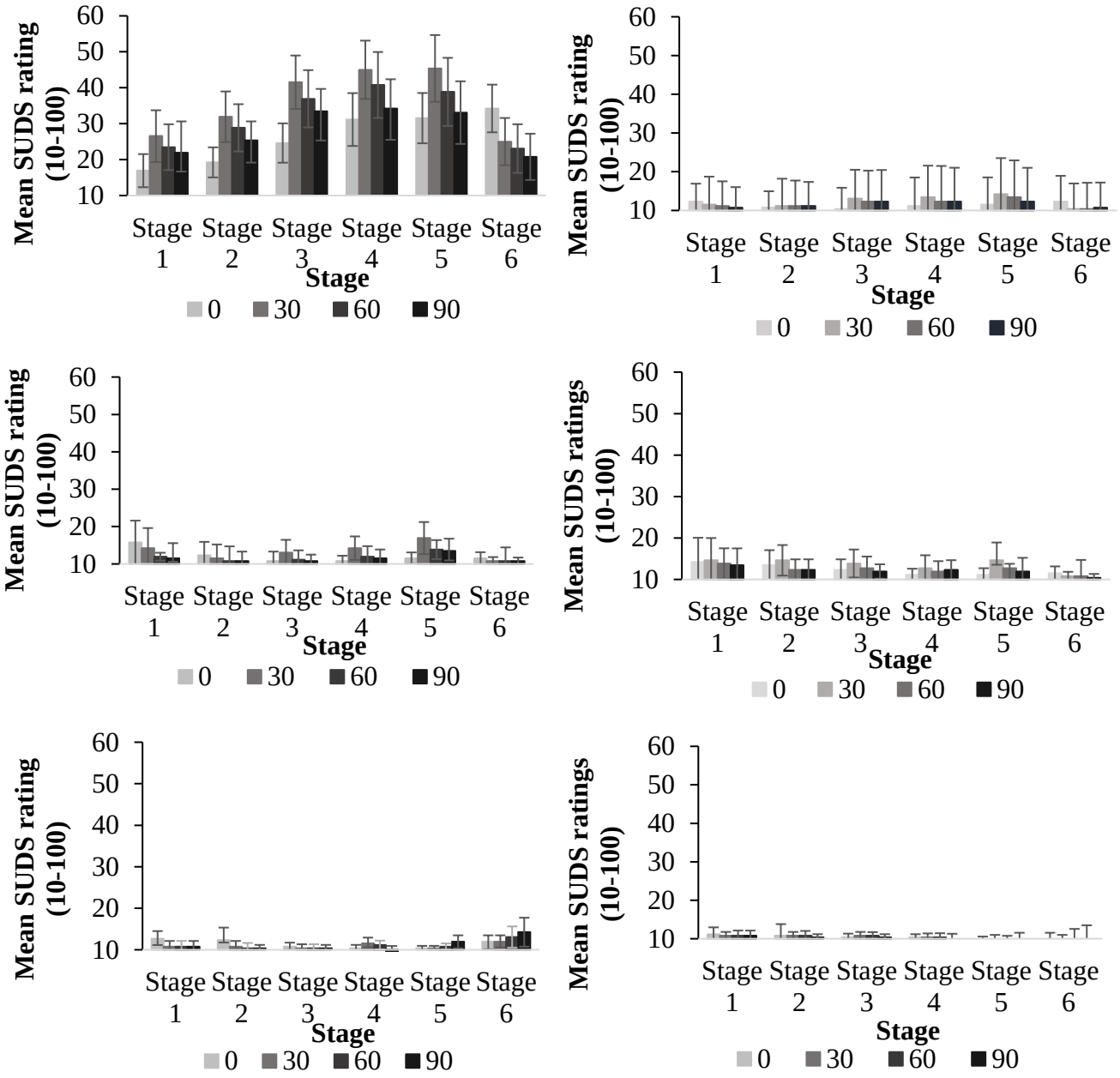

Figure 7. Means SUDS ratings for each timepoint (seconds) within stages 1-6 for spider (row 1), snake (row 2) and bird (row 3) image hierarchies among high (left) and low (right) spider fear participants (error bars represent 95% CIs).

The hypothesised Animal x Stage x Group interaction (see Figure 8), $F(3,80)=5.5$, $p=.001$, $\eta_p^2=.186$, was analysed at Timepoint 2 (30 seconds), specifically, in order to test whether initial fear activation within stages habituated across subsequent stages. The effect of Stage for Spider images was statistically significant for high, $F(2,27)=11.2$, $p<.001$, $\eta_p^2=.483$, and low fear participants, $F(3,33)=4.0$, $p=.017$, $\eta_p^2=.251$ ($\alpha=.017$, Bonferroni corrected). High fear participants provided lower SUDS ratings for the Spider image at Stage 1 compared to at Stages 3 ($p=.021$) and 4 ($p=.021$), which trended towards statistical significance. They also provided significantly lower ratings at Stage 2 compared to at Stages 3 ($p=.006$), 4 ($p=.010$), with Stage 5 ($p=.021$) trending towards statistical significance. Lower ratings at Stage 6 compared to Stage 4 ($p=.019$) also trended towards statistical significance. However, when broken down, low fear participants' SUDS ratings did not statistically significantly differ between stages. The effect of Stage for Snake images trended towards statistical significance for high, $F(3,32)=3.9$, $p=.020$, $\eta_p^2=.247$, but not low fear participants, $F(2,20)=1.2$, $p=.324$, $\eta_p^2=.088$. When broken down, high fear participants' SUDS ratings did not statistically significantly differ between stages. The effect of Stage for Bird images was neither statistically significant for high, $F(2,26)=1.4$, $p=.274$, $\eta_p^2=.102$, or low fear participants, $F(1,17)=1.0$, $p=.360$, $\eta_p^2=.077$.

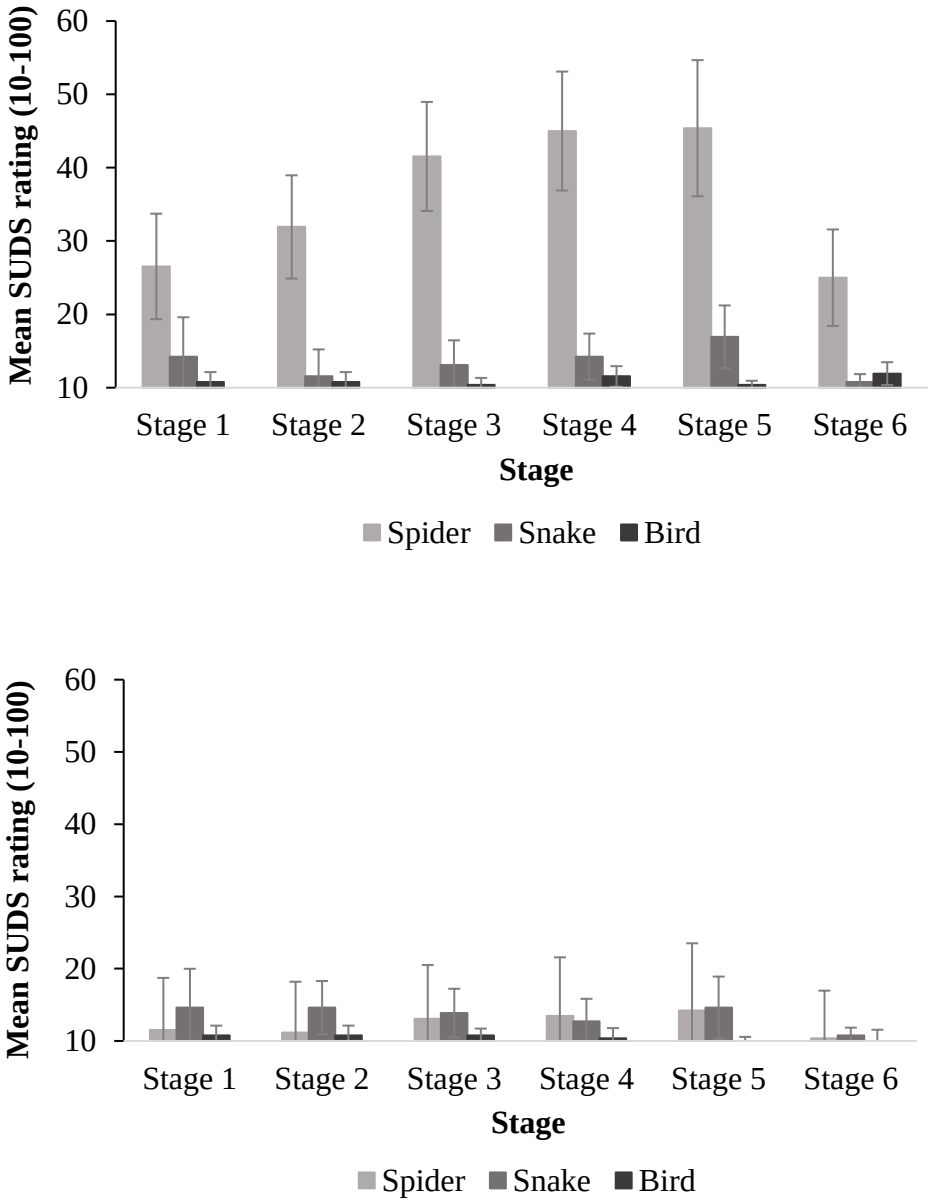

Figure 8. Mean SUDS ratings for the 30 second timepoint (initial fear activation) within stages 1-6 for spider, snake and bird image hierarchies among high (above) and low (below) spider fear participants (error bars represent 95% CIs).

Discussion

The aim of the current study was to further investigate habituation of subjective anxiety (SUDS) and a cortical measure of attentional hypervigilance (P1 amplitude) in specific fear during image-based exposure. As hypothesised, high relative to low spider fear participants reported greater subjective anxiety in response to spider relative to snake and bird images overall. High fear participants also reported reductions in anxiety across timepoints of 30 seconds exposure within later stages (4-6) of the spider image hierarchy, with effect sizes ranging from small to large. This suggests initial fear activation in response to feared stimuli followed by habituation within stages. However, high fear participants did not indicate habituation of initial fear activation (at 30 seconds exposure) across stages of progressively 'scarier' spider images, as expected. Unexpectedly, high relative to low fear participants did not show greater P1 amplitude in response to spider images compared to snake and bird images. However, there was some evidence of habituation in response to spider and snake images, with lower P1 amplitude at Stage 3 compared to earlier stages among both groups. In addition, there was evidence of reinstatement of this response for spider and snake images when the Stage 1 image was repeated at Stage 6.

The absence of enhanced P1 amplitude overall in response to spider images among high spider fear participants is in contrast to previous findings of *specific cortical hypervigilance* (Matthews et al., 2017; Venettacci et al., 2017). However, evidence of fear-specific cortical hypervigilance has been inconsistent. In previous studies, compared to low fear participants, individuals with a spider phobia demonstrated enhanced P1 amplitude in response to spider, neutral, pleasant and

unpleasant images (Kolassa et al., 2007; Kolassa, Musial, Kolassa, & Miltner, 2006; Michalowski et al., 2009). These findings are indicative of *general cortical hypervigilance*. In the present study, evidence of neither specific or general cortical hypervigilance was observed, despite greater self-reported anxiety for spiders among high fear participants. It should be noted that P1 amplitude was averaged across 90 seconds of exposure time for each stage. If P1 amplitude peaked then later habituated within a stage, this may have gone undetected. Further analysis of stage segments would help to clarify this.

P1 amplitude was lower at Stage 3 compared to Stage 1 in the spider image hierarchy and compared to Stages 1 and 2 in the snake image hierarchy for both groups, with moderate and small effect sizes, respectively. This extends previous research (Matthews et al., 2017) where both high and low spider fear participants demonstrated similar habituation of P1 amplitude in response to progressively 'scarier' spider images, albeit overall greater P1 amplitude for high fear participants. In contrast to Matthews et al., reductions in self-reported anxiety between stages were not observed for high fear participants in the current study, although they did report reductions *within* later stages. Further, interestingly, no habituation of P1 amplitude in response to bird (neutral) images was observed in neither group. Previous research has identified differential effects of stimuli valence. Olofsson and Polich (2007) found increases in P1 amplitude for neutral images over repetition, decreases for unpleasant images, and no differences for pleasant images among healthy participants. In the present study, while birds and snakes were selected as neutral and negative non-feared stimuli, respectively, post-task image ratings indicated participants viewed bird images as more pleasant and snake

images as more neutral. Nonetheless, Öhman and Mineka (2001) proposed a fear module involving the amygdala which enables automatic response to evolutionary threat stimuli. Evidence in support of this has been observed in non-fearful participants showing faster responding to evolutionary threat stimuli (i.e., spiders, snakes) compared to non-fear relevant stimuli (Blanchette, 2006). The present finding of decreases in P1 amplitude following exposure to progressively 'scarier' spider and snake images but not non-threat related bird images may therefore suggest habituation of an early sensory process in response to threat-relevant images. This may reflect an adaptive function to screen out irrelevant information and selectively attend to potentially useful stimuli (Rankin et al., 2009).

Both groups demonstrated re-emergence of P1 amplitude at Stage 6 compared to Stage 3 of the spider and snake hierarchies where the repeated image from Stage 1 was shown, with moderate and small effect sizes, respectively. This again extends on results from Matthews et al. (2017) where this finding was shown exclusively using a spider image hierarchy. Authors speculated that stimulus-response associations may have been initially activated at Stage 1 and then re-activated following repetition at Stage 6. In line with an inhibitory learning perspective, fear associations may be reduced during exposure, but not erased entirely (Craske, 2015). The amygdala may work to facilitate reinstatement, given it's role in the storage (Kim, Pare, & Nair, 2013) and retrieval (Erlich, Bush, & LeDoux, 2012) of fear-related memories following exposure to fear-related stimuli. If fear associations were re-activated, a similar re-emergence in anxiety would be expected. However, high fear participants showed a similar level of initial fear activation (30 second SUDS rating) in response to both the initial and repeated spider

image from Stage 1, with no reductions between stages 3, 4 and 5, and reported consistently low anxiety across snake images. Moreover, low fear participants indicated low levels of anxiety across all stages for both spider and snake image hierarchies. It is possible that participants were influenced by demand characteristics. For example, high fear participants may have perceived it to be expected that they would have more anxiety in response to 'scarier' spider images while low fear participants may have expected that they should show consistently low anxiety. Future research may include measures of physiological arousal as objective indices of anxiety.

An alternative explanation for the reductions and re-emergence of P1 amplitude is that participants covertly avoided snake and spider images across Stages 3, 4, and 5, given that these were the 'scarier' images in the hierarchies. For example, using eye tracking, individuals with spider fear have shown preferential fixations on spider images for shorter durations compared to controls during 1-minute intervals, indicating initial hypervigilance followed by attentional avoidance (Rinck & Becker, 2006). This process may explain the absence of enhanced P1 amplitude overall in response to spider images among high fear participants in the current study. Further, such avoidance could explain why subjective anxiety habituated within 'scarier' spider stages but did not generalise across stages among high fear participants. However, it is unclear why low fear participants would behave in a similar manner. Non-fearful participants have also demonstrated shorter time to initially fixate on snake relative to fear-irrelevant images, suggesting hypervigilance to evolutionary threat-related stimuli (Rosa, Gamito, Oliveira, & Morais, 2011). Further research using eye-tracking technology in the current paradigm could help to further explore whether high and low fear groups show

similar patterns of covert avoidance during graded exposure to threat stimuli.

It is also possible that the reductions and re-emergence of P1 amplitude across spider and snake images in both high and low fear participants reflects a *dishabituation* process. *Dishabituation* refers to an increase in response to the original stimulus (Rankin et al., 2009). Research has suggested that this process is independent from *sensitization*, the increase in a response to a novel stimulus (Steiner & Barry, 2014). In previous research with non-fearful participants, habituation of repeated pleasant, neutral and unpleasant images was found within stages for early ERP components, and between stages with reemergence for a novel set of images for late components (Codispoti, Ferrari, & Bradley, 2007). This suggests generalised dishabituation and sensitization across image valence. The present study may extend from this, showing non-fear specific dishabituation of early visual attention for graded threat-images. Future research may aim to replicate and clarify the robustness of this effect across varied exposure presentations, and to distinguish it from sensitization. The mechanism of dishabituation may hold importance for understanding optimal response to exposure. For example, dishabituation generally decreases gradually with application of the dishabituating stimulus (Rankin et al., 2009).

The results of the present study do not support a fear-specific neural process involving habituation and reinstatement of attentional hypervigilance. Furthermore, the findings suggest that reductions in a measure of cortical hypervigilance does not necessarily correspond to decreases in subjective anxiety during graded exposure of feared stimuli. While these results raise further questions, they may provide implications for clinical treatment of anxiety. Evidence is limited to show that

modification of attentional biases results in reductions of anxiety symptoms. For example, while a dot probe task reduced attentional bias to spiders in high spider fear participants, this was only temporary and did not result in greater symptom reduction compared to a control group (Reese, McNally, Najmi, & Amir, 2010). Furthermore, O'Toole and Dennis (2012) found reductions in P1 amplitude for both threatening and non-threatening stimuli following training away from threat. However, state anxiety was reduced irrespective of training away or toward threat. Moreover, attentional focus *toward* threat during extinction learning has been shown to benefit therapeutic outcome (Liao & Craske, 2014). This is line with both Emotional Processing Theory and inhibitory learning perspectives which argue for attentional processing of feared stimuli in order for successful exposure (Podina, Koster, Philippot, Dethier, & David, 2013). However, a meta-analysis indicated a benefit of distraction during exposure at follow-up (Podina et al., 2013). It is therefore of interest to further investigate the relation of reductions in attentional hypervigilance to measures of therapeutic outcome, and to explore a potential role of covert visual avoidance in lapses in extinction learning.

A limitation of the present study includes the use of a passive viewing task. This makes it difficult to determine whether participants attended to images. Future research may overcome this by including behavioural measures or eye tracking technology. Although the groups significantly differed in spider fear, with very large effect sizes, the severity of fear among high fear participants may not have been sufficient to capture the expected processes. Future research should aim to recruit clinically defined samples. Further, the current design permits inference only regarding short-term habituation/dishabituation and more research is needed to explore these effects long-

term following exposure. The present findings for P1 amplitude should be interpreted with caution given the large confidence intervals found. Future research may seek to replicate and identify individual factors associated with reductions and reemergence of early visual attention in response to threat images. Finally, a potential limitation is the use of a hierarchy of progressively 'scarier' images as this makes it difficult to disentangle arousal from habituation. Randomised presentation of similarly rated images may offer less confounded assessment of between-stage habituation.

The aim of the present study was to investigate habituation of a cortical measure of attentional hypervigilance and its relevance to fear-specific subjective anxiety during image-based exposure. Both high and low spider fear participants showed reductions in early attention (P1 amplitude) across progressively 'scarier' spider and snake images, with later re-emergence following repetition of the least 'scary' images. While this may suggest reinstatement of initial fear associations for evolutionary threat stimuli, this did not coincide with similar initial fear activation followed by reductions and re-emergence of subjective anxiety. The re-emergence of P1 amplitude may otherwise suggest dishabituation of early visual attention, or covert avoidance of progressively 'scarier' negative threat stimuli. Greater investigation is needed to clarify the role of these processes in exposure and their relation to therapeutic outcome.

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Appendix A

Participant Video Gaming Experience Questionnaire

Date: _____ Participant: _____

Video Gaming Experience Questionnaire

We are interested in how often you play video games, and may use this information to examine the effects of video game playing on visual attention and motor skills.

How often would you normally play video games? Please choose one response.

- ☐ Never play video games
- ☐ Rarely play video games (less than 2 hours a month)
- ☐ Occasionally play video games (between 30 minutes and 2 hours a week)
- ☐ Regularly play video games (between 2 hours and 5 hours a week)
- ☐ Often play video games (more than 5 hours a week)

Appendix B

Picture rating statistics

Table 1

Descriptive Statistics for Measures of Spider, Snake and Bird Fear

Measure	*n*	*M*	*SD*	Range
Spider fear/10	52	6.08	2.42	1-10
Snake Fear/10	53	5.87	2.39	1-10
Bird Fear/10	53	2.13	1.72	1-9
SPQ/33	51	8.92	6.51	2-24
FSQ/126	49	50.63	30.57	18-115
SNAQ/30	49	9.02	6.16	0-24

Table 2

D*escriptive Statistics for Scariness, Arousal and Valence Ratings for Spider Images*

Image Stage	Scariness (*n*=44)		Arousal (*n*=43)		Valence (*n*=40)	
	M	*SD*	*M*	*SD*	*M*	*SD*
1	5.23	2.69	4.43	3.21	7.78	1.69
2	5.87	2.44	5.18	3.39	8.23	1.61
3	6.42	2.69	5.49	3.76	8.45	1.55
4	6.81	2.71	5.54	3.64	8.64	1.58
5	7.16	2.63	6.03	3.76	8.79	1.83
Range (Min – Max *M*)	4.32-7.16		3.86-6.15		7.50-8.88	

Note. Scariness scores range from 0=not scary at all to 10=highly scary; Arousal scores range from 0=low arousing to 10=highly arousing; Valence scores range from 0=highly pleasant to 10=highly unpleasant.

Table 3

D*escriptive Statistics for Scariness, Arousal and Valence Ratings for Snake Images*

Image Stage	Scariness (*n*=45)		Arousal (*n*=41)		Valence (*n*=42)	
	M	*SD*	*M*	*SD*	*M*	*SD*
1	4.40	2.31	4.71	3.07	6.95	1.59
2	4.78	2.36	5.18	2.94	7.14	1.50
3	5.33	2.32	6.10	2.93	7.34	1.92
4	5.96	2.25	6.75	3.20	8.12	2.22
5	6.45	2.25	6.89	2.84	8.38	1.68
Range (Min – Max)	4.40-6.45		4.71-6.89		6.61-8.38	

Note. Scariness scores range from 0=not scary at all to 10=highly scary; Arousal scores range from 0=low arousing to 10=highly arousing; Valence scores range from 0=highly pleasant to 10=highly unpleasant.

Table 4

D*escriptive Statistics for Scariness, Arousal and Valence Ratings for Bird Images*

Image Stage	Scariness (*n*=40)		Arousal (*n*=42)		Valence (*n*=40)	
	M	*SD*	*M*	*SD*	*M*	*SD*
1	1.08	0.28	3.07	2.57	3.38	2.16
2	1.10	0.50	3.17	2.57	3.53	2.07
3	1.13	0.40	3.21	2.69	3.23	2.09
4	1.05	0.25	3.05	2.59	3.28	2.01
5	1.03	0.19	3.05	2.63	3.20	2.30
Range (Min – Max)	1.03-1.13		3.05-3.83		2.43-3.53	

Note. Scariness scores range from 0=not scary at all to 10=highly scary; Arousal scores range from 0=low arousing to 10=highly arousing; Valence scores range from 0=highly pleasant to 10=highly unpleasant.

Appendix C
Image Hierarchies

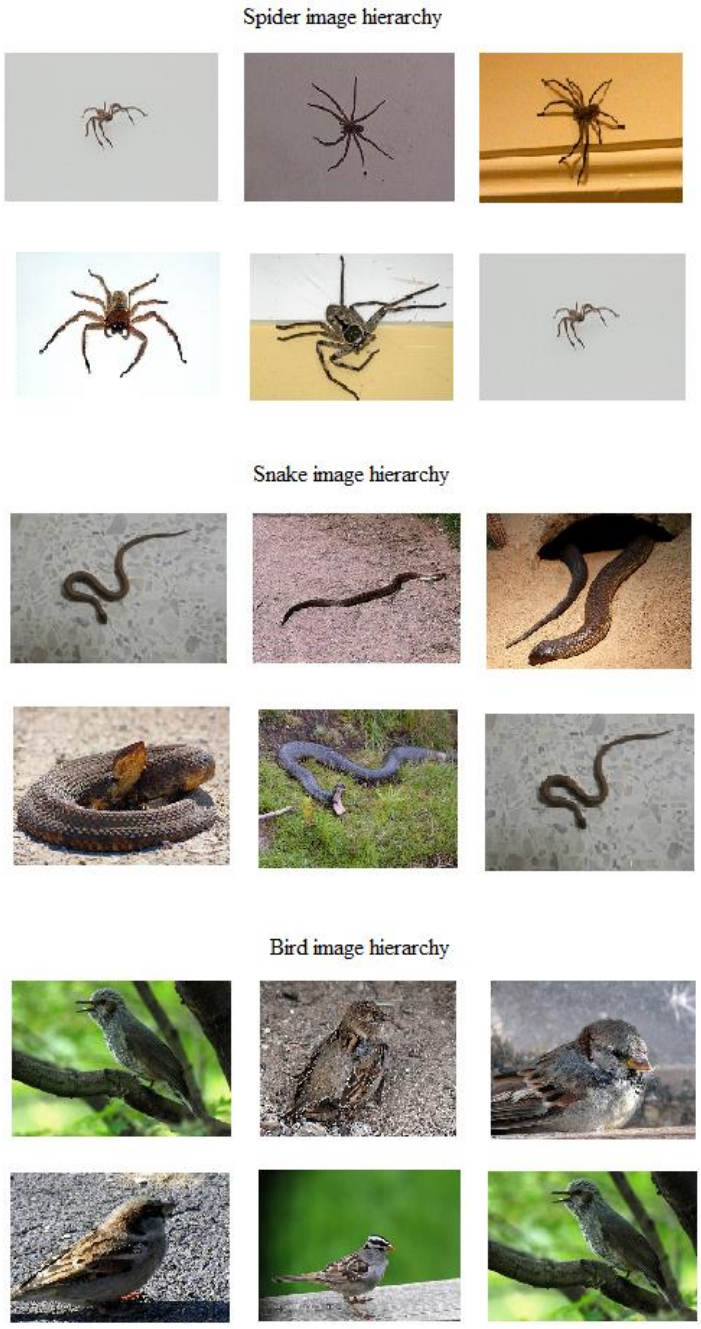

Figure 6. Images for Stages 1 to 6 (shown from left to right) for the fear-relevant (progressively 'scarier' spider images), negative non-fear relevant (progressively 'scarier' snake images) and neutral (stable neutral bird images) image hierarchies. Stage 6 comprises the Stage 1 image repeated in each hierarchy.